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Compendium of CARDEROCKDIV Articles Published in Navy Domestic Technology Transfer *Fact Sheet*, Jan 1990 through Dec 1992

Edited by
Dr. Basil V. Nakonechny

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The Carderock Division (CARDEROCKDIV), Naval Surface Warfare Center is an active participant in various technology transfer activities sponsored by the U.S. Navy, such as the Navy Potential Contractor Program (NPCP), Cooperative R&D Agreements (CRDAs or CRADAs), the Federal Laboratory Consortium (FLC) for Technology Transfer, and the National Technology Transfer Center (NTTC). This report is the second of two reports that contain CARDEROCKDIV articles published in the U.S. Navy Domestic Technology Transfer *Fact Sheet*. The first report, DTRC-90/CT07 (June 1990) covered the period December 1975 through December 1989 and included 120 articles. This compendium of 29 articles covers the period January 1990 through December 1992.

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PREFACE

Since its inception in December 1975, the U.S. Navy monthly publication *Fact Sheet* has provided a forum for selected current naval R&D technology items that promise high potential benefit for civilian applications. The Carderock Division (CARDEROCKDIV), Naval Surface Warfare Center has used this medium to bring a wide range of Navy sponsored R&D technologies to the attention of potential users, both within and without the Navy's technical community. This mode of Technology Transfer often leads to innovative and novel byproducts, processes, and techniques having applications well beyond the needs of the fleet (i.e., to the industrial and commercial sectors, as well as to state and local governments).

The informal process of "technology transfer" has been strengthened in recent years by two Public Laws, the Stevenson–Wydler Technology Innovation Act of 1980, P.L. 96–480, and the Federal Technology Transfer Act of 1986, P.L. 99–502.

The Carderock Division, NSWC is an active participant in various domestic technology transfer activities sponsored by the U.S. Navy, such as the Navy Potential Contractor Program (NPCP), Cooperative Research and Development Agreements (CRDAs or CRADAs), the Federal Laboratory Consortium (FLC) for Technology Transfer, and the National Technology Transfer Center (NTTC). This report is the second of two reports that contain CARDEROCKDIV articles published in the U.S. Navy Domestic Technology Transfer *Fact Sheet*. The first report, DTRC–90/CT07 (June 1990) covered the period December 1975 through December 1989 and included 120 articles. This compendium of 29 articles covers the period January 1990 through December 1992.

The Division's Administrative and Technical Departments and their staff are commended for their continuous effort, contributions, and assistance in support of the publication U.S. Navy Domestic Technology Transfer *Fact Sheet*.

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Effect of High Flow On Calcareous Deposits and Cathodic Protection Current Density

Scientists at the David Taylor Research Center (DTRC), Annapolis, Maryland, have been studying the effect of flowing seawater on structures with calcareous deposits to determine the cathodic protection current demand by using a modified rotating cylinder electrode.

The study determined that calcareous deposits reduce cathodic current demand by two orders of magnitude over freshly exposed material, and the effect of velocity on current density of material with a deposit was well under an order of magnitude from 1,000 to 10,000 RPM (9 to 90 ft/s).

HY-80 steel, nickel-aluminum bronze, and alloy 625 were evaluated at velocities of up to 90 ft/s. It was determined that calcareous deposits do not appear to form readily or adhere properly to nickel-aluminum bronze or alloy 625 in flowing seawater, but can be easily formed under low flow conditions. Steel will form calcareous deposits even under flowing conditions, although the rate of formation was not studied. Once formed, these deposits are not removed by short exposures to high velocity flow up to 90 ft/s.

Although materials may be used under conditions of intermittent operation, allowing the formation of the deposits, cleaning to remove fouling or prolonged high velocity operation may remove them. Thus, for many applications under high flow, the presence of calcareous deposits cannot be relied on. Conservative design for a cathodic protection system for a periodically cleaned structure or machinery component may necessitate not considering the effect of the deposits.

Dr. Harvey Hack
February 1990

Mercury Waste Minimized

Mercury is one of the most hazardous materials carried onboard U.S. Navy ships. As much as 10 gallons per week of mercury-contaminated water is generated from testing boiler water and boiler feedwater. Scientists at the David Taylor Research Center (DTRC), Bethesda, Maryland, have evaluated an ion exchange cartridge for removing and retaining mercury ions from the waste water so that the waste water can be discharged at sea; resulting in waste disposal, cost savings, labor savings, and increased safety onboard ship.

After testing four different resins, scientists determined that Duolite GT-73 provided the best mercury removal performance. It also has a shelf life of at least two years when stored in sealed cartridges. One and one-half liters of Duolite GT-73 is contained in an 8-centimeter diameter, 30-centimeter long cartridge. Two centimeters of Duolite A561, a weakly basic anion resin, are added to the top of the cartridge to remove minute particles. An apparatus was designed to hold the cartridge and an influent reservoir so that the resin is kept wet.

This cartridge system was installed and evaluated on the U.S.S. *Constellation* (CV 64) where 250 gallons of waste water were processed with a single cartridge. Additional cartridges have been installed on four other ships to confirm the replacement interval and to assess operating and maintenance requirements of the system.

Craig Alig
February 1990

Screw Compressor Air Conditioning Plant Being Developed for Surface Ships

The David Taylor Research Center (DTRC) has been developing high-efficiency screw compressor air conditioning (AC) plant technology for naval surface ship applications. The screw compressor AC plant design is compact, lightweight, reliable, energy efficient, and uses environmentally acceptable Refrigerant-22 (R-22). The R-22 screw compressor AC plant is a viable alternative to existing shipboard R-12 reciprocating compressor and R-114 centrifugal compressor AC plant designs, which are generally large, heavy, and inefficient. Both R-12 and R-114 are Chlorofluorocarbon (CFC) refrigerants that are responsible for the depletion of the earth's protective stratospheric ozone layer, and under international agreements will be unavailable after the year 2000. The screw compressor AC plant design is 30 percent smaller, 30 percent lighter, and provides 50 percent energy savings when compared to the existing fleet reciprocating and centrifugal compressor AC plant designs. If a typical surface ship with four 250-ton cooling capacity AC plants was retrofitted with four high-efficiency screw AC plants, energy savings of approximately 2 million kilowatt hours per year would result.

Gregory Brunner
May 1990

Microchips

Under the sponsorship of the Office of Naval Technology (ONT), the David Taylor Research Center (DTRC) has demonstrated the feasibility of using microchips to keep maintenance records of aircraft components right on the component itself rather than on paper files located in some remote location. Under the ONT project, microchip tags containing maintenance and configuration records were attached to key components of a CH-46 helicopter during an eight-month period of operation. The data on each tag were periodically downloaded via a portable scanner. Application of this technology in the future is expected to reduce maintenance costs, improve inventory control and preclude the loss of certification data.

James Chesley
July 1990

Lower Bound Properties from Material Test Data Performed

Monte Carlo simulations were performed at the David Taylor Research Center (DTRC) to determine how the accuracy of lower bound values estimated from experimental data is influenced by sample size, required confidence level, and assumed statistical model. Population distributions having different degrees of skewness, selected to bracket those expected in actual experimental data, were studied. For nearly every case considered, lower bound estimates calculated using Log-Normal statistics were more accurate than estimates calculated using either Normal or Weibull statistics.

It was demonstrated that testing more than three samples per condition can greatly reduce the error associated with the lower bound estimate. However, after the twelfth sample, no additional sample will reduce the lower bound estimation error by more than 2.5 percent for all statistical distribution/confidence level combinations considered. When applied to material properties for which the population distribution has been established by previous testing, it was demonstrated that a Monte Carlo simulation can be used to assess the maximum expected lower bound estimation error as a function of sample size and confidence level. This information can be used to determine the minimum number of specimens needed to obtain a lower bound estimate of acceptable accuracy when sampling a known population.

Dr. Mark T. Kirk
August 1990

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Drug Runner Views PHM

The David Taylor Research Center (DTRC) has provided the focal point for U S Navy hydrofoil development over several decades, including the technical management of the PHM program during the 1970s. The Center continues to provide technical assistance to Chief of Naval Operations (OPNAV) and Naval Sea Systems Command (NAVSEA) for PHM logistics support, PHM improvements, and future hydrofoil designs.

Many drug runners operating in the Gulf of Mexico and the Florida Straits have learned what it means to look down the barrel of a 76mm Otto Melara cannon on the deck of a PHM. The U S Navy/U S Coast Guard joint operations frequently result in a lengthy chase of *go-fast* boats.

The Navy's PHM hydrofoils represent only 3% of the Navy's surface combatants, but they have been responsible for 30% of the Navy's overall drug busts. Because of *El Terror Gris que Vuela* (*The Gray Terror that Flies*, Figure 1), there has been a decrease in surface drug operations in the Florida Straits during the last several years. This has forced the PHMs to operate much further away from home ports on longer patrols in such areas as the Yucatan Peninsula and from naval bases at Guantanomo Bay and Roosevelt Roads.

John Meyer
December 1990

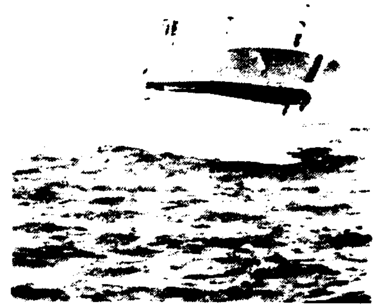

Figure 1. The Gray Terror

EMLI Completes Testing

The Electromagnetic Tank Level Indicating (EMLI) System, developed at the David Taylor Research Center (DTRC), Carderock, Maryland, has successfully completed Advanced Development Model (ADM) testing. The EMLI (Figure 1) is a highly reliable sensor for measuring the quantity of fuel oil in seawater compensated storage tanks. Designed as the next generation tank level indicator (TLI) for shipboard use, the microprocessor based EMLI is fully automatic and has no moving parts.

The EMLI technique is based on time domain reflectometry (TDR), which is used primarily for the inspection of long transmission cables. TDR is analogous to radar in the sense that a high-frequency signal is transmitted onto a cable and reflections from impedance mismatches and cable damage are measured. The location and amplitude of these can be determined from the TDR signal. The EMLI uses TDR and an open, fiberglass, transmission line sensor to interrogate the contents of shipboard fuel tanks.

The tank contents act as the transmission line dielectric with impedance discontinuities occurring at the tank fluid interfaces. A unique algorithm, developed by DTRC engineers, allows the system to accurately determine the depth of the fuel oil and the seawater in seawater ballasted fuel oil tanks. In addition, the presence of an oil and seawater emulsion can be detected and measured, and the rugged fiberglass probes resist coating and corrosion. The EMLI is not limited to fuel oil tanks but may be applied to a variety of difficult level-sensing problems. The EMLI promises to be a low-cost, highly reliable, and rugged successor to TLIs currently in use by the fleet.

Christopher Nemarich
January 1991

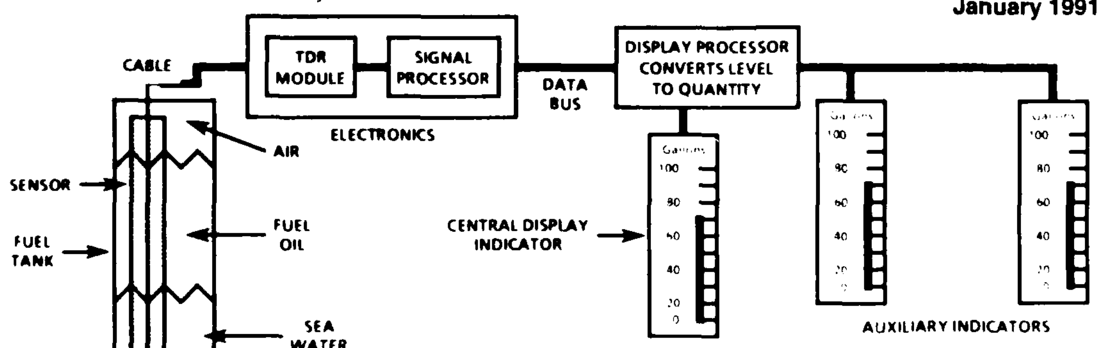

Figure 1 Electromagnetic tank level indicator

Damping of Aluminum-Indium Alloys Examined

The David Taylor Research Center (DTRC), Carderock, Maryland, and the University of Michigan, have examined high damping aluminum-indium alloys. The strain amplitude dependent damping of binary aluminum-indium alloys containing nominally 0.6 to 17.3 weight percent indium was studied. A dynamic mechanical analyzer was used to measure the damping capacity of these materials. Pure aluminum (99.99%) exhibited strain dependent damping at strain values as low as 70 microstrain. The addition of 0.6 weight percent indium reduced the strain independent damping by a factor of 2, but the strain dependent damping was equivalent to that of pure aluminum.

Binary aluminum-indium alloys containing 4, 8, 12, and 16 weight percent indium exhibited a general increase in loss factor with increasing indium content; however, the strain dependent damping was no greater than that of the pure aluminum sample. No significant increase in damping was observed when the binary alloys were tested at temperatures above the melting point of indium. Two damping peaks were observed near the eutectic melting point when tested at 10 Hz, and differential scanning calorimetry verified both of these peaks as due to the melting of the indium inclusions. It was concluded that the higher temperature damping peak was associated with smaller indium inclusions and that the damping peaks were related to the solute segregation associated with the binary eutectic reaction.

Catherine Wong
March 1991

Fiber-Optic Hydrophone Developed

Fiber-optic sensors have been demonstrating the capability of measuring most physical quantities with potentially high levels of sensitivity and precision. A planar fiber-optic, acoustic sensor that provides the Navy with a low flow-noise hydrophone has been under joint development by the David Taylor Research Center (DTRC), Carderock, Maryland, and the Naval Research Laboratory (NRL), Washington, D.C. The same hydrohone, because of its low flow-noise characteristics, is also ideally suited for determining the low wave-number pressure components of fluctuating pressures underneath a turbulent boundary layer (TBL). When the wave-number characteristics of the TBL pressure fluctuations match well with the wave-number responses of the structure of an underwater vehicle, the structure becomes easily excited and the resulting vibration can be a noise source. Therefore, it is necessary to have an accurate description of the wall pressure fluctuations underneath a TBL in studying flow/structure interaction problems. The same pressure fluctuations also become unwanted noises (flow noise), which affect the hydrophone's ability to measure acoustic energy.

A photograph of the planar fiber-optic hydrophone is shown in Figure 1. Unique features of the current fiber-optic hydrophone design are its insensitivity to vibration and acoustical transparency. The insensitivity to vibration may allow direct mounting of the hydrophone on a structure. The acoustical transparency can provide array designer with additional signal processing advantages by constructing arrays with multiple layers of the hydrophone. The acoustic sensitivity is the best among all reported planar fiber-optic sensors. Experiments also showed that the fiber-optic hydrophone was better at rejecting vibration responses than a DVF_2 hydrophone of similar geometry. The acoustic transparency of the hydrophone was also experimentally verified through insertion loss measurements.

Dr. Paul C. Shang
April 1991

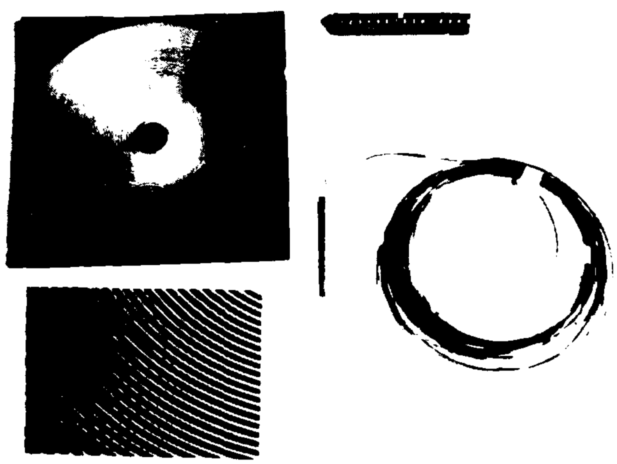

Figure 1. Planar fiber–optic hydrophone

Correlation of Elastic-Plastic Fracture Toughness Studied

The David Taylor Research Center (DTRC), Bethesda, Maryland, has been studying the correlation of elastic-plastic fracture toughness. Single edge-notched bend (SENB) specimens containing shallow cracks (a/W < 0.2) are commonly employed for fracture testing of ferritic materials in the lower-transition region where extensive plasticity (but no significant ductile crack growth) precedes unstable fracture.

Critical J-values (J_c) for shallow-crack specimens are significantly larger (factor of 2-3) than the J_c values for corresponding deep-crack specimens at identical temperatures. The increase of fracture toughness arises from the loss of constraint that occurs when the gross plastic zones of bending impinge on the otherwise autonomous crack-tip plastic zones. Consequently, SENB specimens with small and large a/W ratios loaded to the same J-value have markedly different crack-tip stresses under large-scale plasticity. Detailed, plane-strain finite-element analyses (**Figures 1 and 2**) and a local stress-based criterion for cleavage fracture are combined to establish specimen size requirements (deformation limits) for testing in the transition region, which assure a single parameter (J) characterization of the crack-tip stress field. Moreover, these analyses provide the first quantitative framework to correlate J_c-values with a/W ratio once the deformation limits are exceeded. The new procedures are directly applicable to estimate the toughness values for shallow crack specimens from results of tests performed on conventional deep-crack specimens. The increased toughness values for shallow crack specimens are required to perform realistic assessments of the surface-breaking defects most commonly encountered in structures.

The correlation procedure is applied to an extensive set of test results for an A36 steel and is shown to successfully correlate the a/W ratio effects on the measured fracture toughness values in the transition range.

Dr. Mark T. Kirk
May 1991

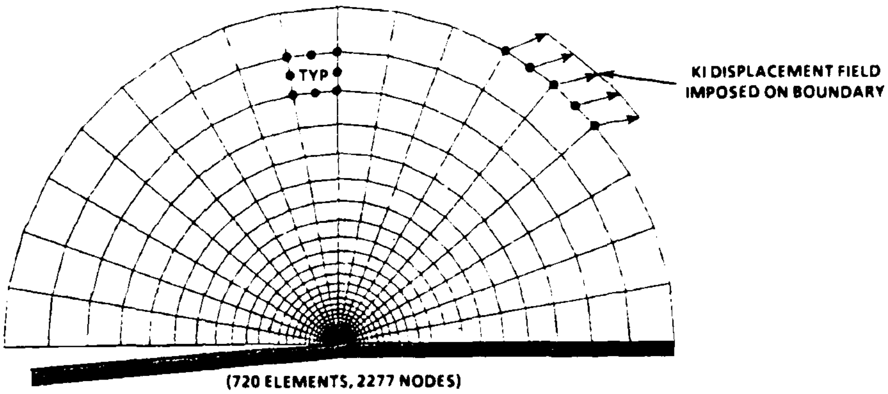

Figure 1. Finite-element mesh for the small-scale yielding computations

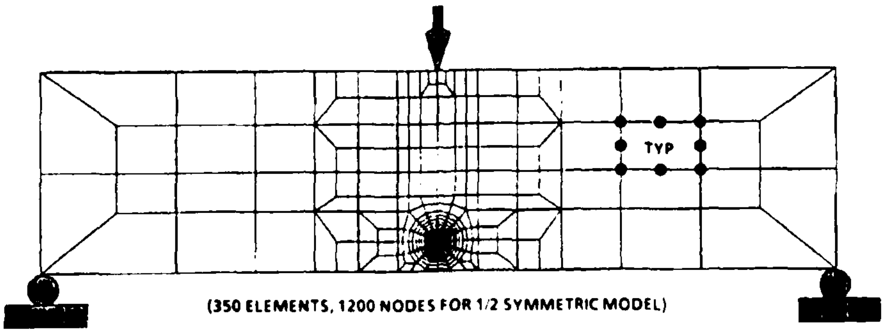

Figure 2. Typical finite-element mesh for plane strain analyses of the SENB specimens

Defect Area Determines Organic Coating

Coating breakdown is a major maintenance cost on ships. It is therefore desirable to have a rapid technique for predicting or evaluating coating performance nondestructively.

The breakpoint frequency method, which allows determination of the electrochemically active area of a coated metal in seawater was refined and used by the David Taylor Research Center (DTRC) scientists at Bethesda, Maryland. A computer model is used to explain the basis of the breakpoint method, and the model is compared to impedance and visual data from epoxy-coated steel panels in ASTM artificial seawater with and without an intentional defect of known area.

The breakpoint frequency method was extremely useful in determining the electrochemically active area of coated steel in seawater. The equivalent circuit model used in this analysis was capable of fitting actual data on coated steel panels with and without an intentional defect. A correlation was obtained between the breakpoint frequency and the visually estimated electrochemically active area on epoxy coatings of a variety of thicknesses. This method offers a simple alternative to determination of defect areas via the use of the pseudocapacitance from difficult-to-analyze, low frequency impedance data. This approach also can detect the beginnings of coating breakdown long before visual indications are present.

Dr. Harvey Hack
June 1991

Fire Testing Tool Installed

The David Taylor Research Center (DTRC), Carderock, Maryland, has recently completed installation of a Cone Calorimeter (Figure 1). This new test apparatus, developed by the National Institute of Standards and Technology (NIST) and modified for extended analytical capability by DTRC, provides a bench-scale test of a material's fire hazard characteristics. This will greatly aid DTRC in its responsibilities of fire testing new materials before approval for fleet use.

A Cone Calorimeter test provides a wealth of information about a material's fire behavior, unlike many standardized, small-scale test methods that provide information on just a single fire hazard characteristic. During a test, the exhaust flow is monitored for concentrations of O_2, CO_2, CO, and hydrocarbons as well as several toxic gases, such as hydrogen cyanide (HCN) hydrogen halides (HF, HCl, HBR) and oxides of nitrogen (NO, NO_2, NO_X). Burning a specimen in the Cone Calorimeter provides the following fire hazard properties: time-to-ignition, smoke generation, the heat of combustion, and the rate of heat release (RHR). The heat of combustion is based on the rate of mass lost over the course of the test, and the RHR is based on the percentage of oxygen depleted from the exhaust flow. The information gathered from this bench-scale test can accurately predict a tested material's behavior in a large-scale test.

The Cone Calorimeter is quite versatile in that it can be used to test liquids and small sections of cables as well as surface coatings (paints, primers, and sealers) on a standard 10-centimeter square sample. The arrival of the Cone Calorimeter coincides with an influx of many new composite materials and has proved invaluable in helping DTRC keep up with their rapid pace of development. The Cone Calorimeter is also aiding in the application of embedding fiber-optic thermocouples in composite materials in order to understand structural failure modes under fire conditions. In the future, the Cone Calorimeter is expected to help direct development of composite materials with fire retardant properties.

John R. Ness
July 1991

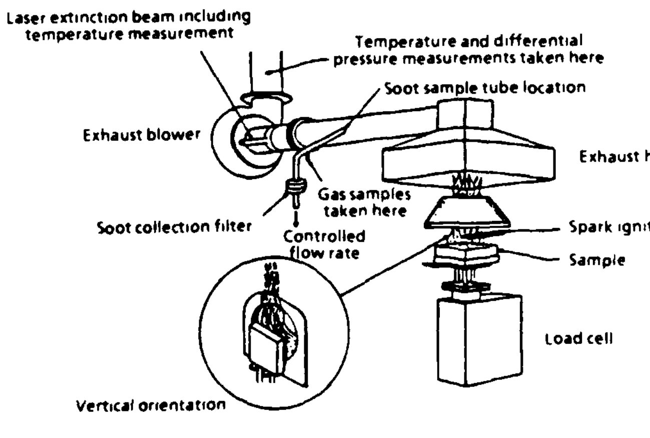

Figure 1. Cone Calorimeter

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Turbomachine Blade Noise Flow Analysis

The David Taylor Research Center (DTRC), Carderock, Maryland, has made an unsteady three-dimensional potential flow analysis of the velocity and pressure fields associated with moving blade rows. The technique requires that each blade be described by an attached vortex loop composed of the bound starting and shed vortex lines. As the blades rotate, the time variation of the combined velocity potentials from these vortex systems yields the fluid enthalpy change due to shaft power and an increase in the vortex loop area. The vortex area change is a direct effect of the blade force on the fluid and is shown to be equivalent to the continuous insertion of volume dipoles into the flow. These dipoles may then be readily interpreted as sources of acoustic energy. For turbomachines in internal fluid systems, this unified analysis provides an accurate prediction of the mechanical energy transfer. However, it predicts a tonal acoustic radiation that is much lower than observed experimentally. For internal flows, acoustic reflections rotor-stator interactions and inlet, as well as self-generated, turbulence, must be included in the analysis. Real-time flow visualization experiments are recommended to identify the additional unsteady vortex systems that serve as sources for the excess sound.

Dr. Earl Quandt
August 1991

ESCA Studies of Marine Conditioning Films Performed

Immersion of a solid surface into a body of natural water exposes the surface to both the water itself and to a variety of dissolved materials. Because the absorption process is usually faster than perceived on corrosion or biological colonization, the degree to which the absorbed layer affects subsequent events is important in the control of biofouling and corrosion of naval equipment. In this work conducted by the David Taylor Research Center (DTRC), Carderock, Maryland, Electron Spectroscopy for Chemical Analysis (ESCA) studies of the nature of the films formed during immersion in the natural water of the Severn estuary are performed and compared with ESCA signals obtained from samples of known substances in natural waters (Figure 1). The variables affecting the nature of the film on copper-nickel alloy included the biogeochemical state of the estuary, as determined by the season and the electrochemical potential. Immersion of a sample of the plastic poly [vinyl chloride] (PVC) did not result in perceptible absorption, but immersion of poly [fluoroethylene-propylene] (FEP Teflon) resulted in a clear change of the carbon and oxygen ESCA signals, indicating significant absorption. Both sulfides and protein-related components in natural saline waters have been implicated in accelerated corrosion of copper and its alloys. These findings indicate the detectability of these substances after shore exposure and show that their presence is related to the exposure conditions.

Dr. George I. Loeb
September 1991

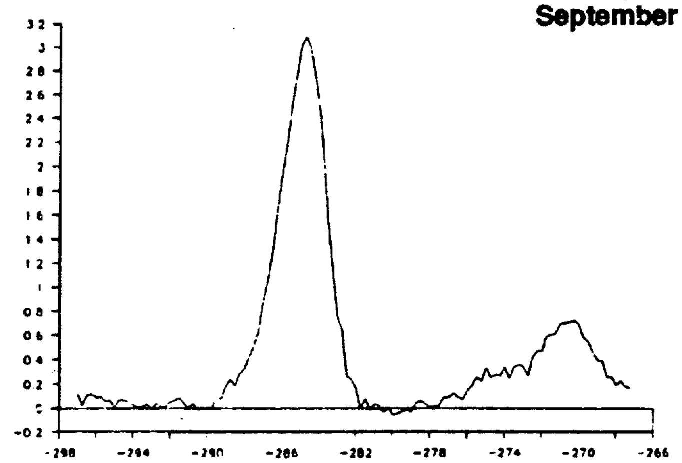

Figure 1. ESCA carbon signal of exposed PVC

Composite Pumps Used on Shipboard

The David Taylor Research Center (DTRC), Annapolis, Maryland, is conducting an effort to develop a family of corrosion-free and erosion-resistant centrifugal pumps made from polymer-matrix and fiber-reinforced composite material for shipboard use. The effort to develop Navy standard composite pumps began with a survey to determine the potential impact composite pumps could have within the Fleet. The study determined that the reduction of corrosion/errosion damage, weight savings, reduced maintenance, lower acquisition costs, and the potential for lower pump noise levels accompanying the use of composite material pumps would benefit a great number of Fleet pump applications.

Once the projected impact of composites was determined, physical evaluations were conducted to determine the hydraulic, mechanical, and material properties of currently available commercial composite pumps. The information derived from these evaluations was provided to the Naval Sea Systems Command for the development of a military specification and the design of Navy composite pumps.

In addition to the study and evaluations, several prototype commercial close-coupled composite pumps were installed onboard Navy ships as a demonstration of their ability to perform in that demanding environment. The next step in this sequence to develop Navy composite pumps will be to procure pumps complying with the military specification and Navy design for laboratory and shipboard evaluations.

Dennis W. Suitt
October 1991

Spray Forming Process Developed

Spray forming has proven to be a viable, cost-effective alternative to conventional metal-working technology for the production of near net shape material preforms (tubular, plates, and discs) with properties surpassing those of their cast and wrought counterparts. The Spray Forming Technology Facility at the David Taylor Research Center (DTRC), Carderock, Maryland, is in full operation for the study and development of near net shape manufacturing processes. DTRC is the only government agency with this capability and is considered the national center for military applications in spray forming. Current programs are aimed at optimization of the process, certification of the spray formed products, and industrialization of the technology.

A current program sponsored by the Office of Naval Technology involves the development of robust, real-time sensors interfaced with an automated fuzzy logic controller and expanded motion control system. The improved system will have the capability to manufacture low-cost, improved-performance, non-symmetric components currently producible only by casting or forgings. Through a Foreign Comparative Test Program, sponsored by the Office of the Secretary of Defense, commercially available spray formed piping from foreign sources is currently being evaluated and certified for near-term use in the fleet. Industrialization efforts are aimed at the establishment of domestic capabilities as there are no commercial facilities in the United States to date. The Center has just initiated a manufacturing technology program, the intent of which is to develop a commercial plant in the United States capable of producing large military components. In addition to the above programs, the Center's Spray Forming Technology Group is addressing new applications in bimetallics and composite materials.

Dr. Angela Moran
November 1991

Acoustic Diagnostics Using a Remotely Operated Vehicle

The David Taylor Research Center (DTRC), Carderock, Maryland, has developed an Override Noise Measurement System for Acoustic Diagnostic Investigations. The system consists of an acoustic sensor mounted on a computer-controlled, remotely operated vehicle (ROV), a tethered unmanned underwater robot (Figure 1). Any underwater structure or ship hull can be acoustically evaluated by positioning the ROV and hydrophone probe at various locations along the structure where it will measure the sound pressure levels. Different shipboard equipment can be operated to evaluate each system's contribution to the overall acoustic profile. Because the Overside System is capable of measuring the acoustic intensity field in close proximity, it is able to detect and accurately locate noise sources. Corrective action can then be taken to eliminate the noise source.

Typically, ROVs are controlled by an operator who uses hand-held joysticks to activate the ROV's thrusters to achieve the desired vehicle motion. However, the limited underwater visibility and lack of visual reference points for the operator make it necessary to use an underwater navigation system and computer-based controller to accurately position the ROV relative to the hull. The navigation system obtains the location of each of the transceivers mounted on the ROV and translates it into an ROV position and heading. This position is then compared with the desired position, and the computer activates the appropriate thrusters to move the ROV to the desired position. When the vehicle is at the specified point, the ROV enters a hover phase; the vehicle will maintain that position until instructed to move. A computer data file of desired hover points along the hull can be created ahead of time, and at the time of deployment, the vehicle can be commanded to go to any of these points.

The ROV's acoustic probe consists of a boom from which two dual element, phase method, hydrophones are resiliently mounted to form a line array. The relative spacing between the hydrophone elements is preset and determined by the frequency range to be measured.

While taking acoustic measurements, the ROV follows a path defined by a matrix of grid points that describe an imaginary control surface one meter away from the structure. The ROV then measures the sound pressure levels and phase angle between both hydrophones as it hovers at each grid point. A dynamic signal analyzer is used to extract sound intensity from these measurements, which allows the operator to assess predominant frequencies and levels while the measurements are in progress. The intensity data from each grid point are then summed over the entire grid and post processed to develop sound intensity contour plots. These sound intensity contours can be superimposed on an outline of the structure to ease interpretation of the acoustic survey's results. The Overside System can be used in a harbor or pier side environment because of the sound intensity method's ability to discriminate against background noise. The integration of the positioning system with the computer-based control system allows us to position the ROV very accurately in zero visibility conditions. The Overside System is portable and can be deployed rapidly at any port without support from shipyard personnel. As a result, acoustic diagnostic work can be performed with minimal impact on schedules.

Dana Lynn
December 1991

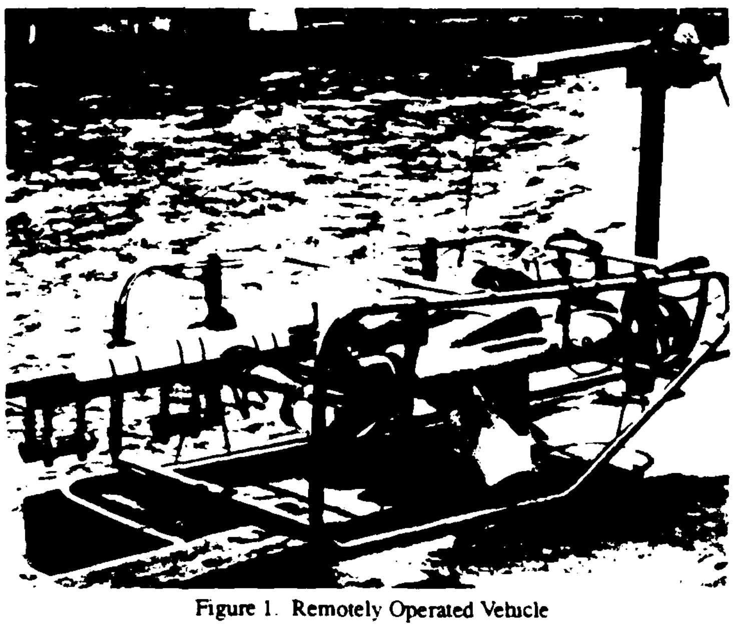

Figure 1. Remotely Operated Vehicle

Microencapsulation of Biocides Used in Antifouling Coatings

Microencapsulation is used in many industries to control the release, protection, and/or isolation of a material. The Carderock Division of the Naval Surface Warfare Center, Carderock, Maryland, has been applying these characteristics to antifouling (AF) coatings to enhance their performance, increase their versatility, and minimize environmental impact.

The most effective modern AF coatings (3 to 5 years) currently used by the Navy are based on ablative copper technology. However in the near future, tighter environmental regulations may limit or even eliminate the use of cuprous oxide, and therefore alternative effective means must be sought for fouling control. Microencapsulation may provide an avenue for readily incorporating new AF and their combinations into existing paint matrices without the need for extensive reformulation. Microencapsulation may also provide the release control necessary to maintain or even extend current coating lifetimes.

Capsules containing tributyl tin chloride, tributyltin fluoride, simazine, or benzoic acid have been made and incorporated into a vinyl rosin paint matrix alone and in combination. These coatings are currently undergoing AF and release rate evaluation. Future work will involve optimizing microcapsule characteristics, surveying other toxins or active agents and their combinations, and continued evaluation of AF performance and release rate testing.

Elizabeth Haslbeck
January 1992

Compression of Thick-Section Composites Investigated

The Carderock Division of the Naval Surface Warfare, Carderock, Maryland, conducted an investigation that deals with the compression response of composite materials between 0.25 and 1.0 inches thick. The objective was to experimentally and theoretically determine the effect of thickness on the elastic properties, strength, and failure mechanisms in carbon and fiberglass-reinforced composite materials (Figure 1).

The 48-, 96-, and 192-ply (0.25-, 0.50-, and 1.0-inch) thick AS4/3501-6 and S2/3501-6 panels were fabricated with unidirectional and $[0_2/90]_{ns}$ stacking sequences. A compression test method (Figure 2) was designed that allowed the evaluation of these materials in compression. Inplane and through-thickness properties were evaluated. Fractography and high-speed video recordings were used to investigate the failure mechanisms of the thick materials considered.

The inplane moduli, inplane and through-thickness Poisson's ratios, compression strength, and failure mechanisms were all shown to be independent of material thickness. The predominant failure mechanisms for both materials were kink bands and delaminations, and they were identical in geometry to that which has been reported for composite materials in the range of 0.1 inch in thickness.

The inplane and through-thickness elastic properties of the $[0_2/90]_{ns}$ laminates were accurately predicted from measured 3-D lamina properties using an exact 3-D theoretical solution for effective laminate properties. The effect of fixture imposed through-thickness restraint on laminate failure was theoretically documented. This effect was shown to account for the 20-percent drop seen in the compression strength of the thick $[0_2/90]_{ns}$ laminates.

The combination of the experimental and theoretical results presented make a strong case for the further development of compression failure theories that are based on kink-band formation as the primary failure mechanism.

The most important finding for thick composites in compression was that the matrix dominated properties E_2, V_{23}, and V_{xz} exhibited significant nonlinearities. These nonlinearities were shown to be material nonlinearities and were reversible during unloading of the compression specimens. Changes of up to 80 percent in material properties were recorded as a result of these nonlinearities, and these changes could have significant impact on the analyses conducted on components fabricated from thick-section composites.

(Continued on page 11)

Compression of Thick-Section Composites Investigated (Continued)

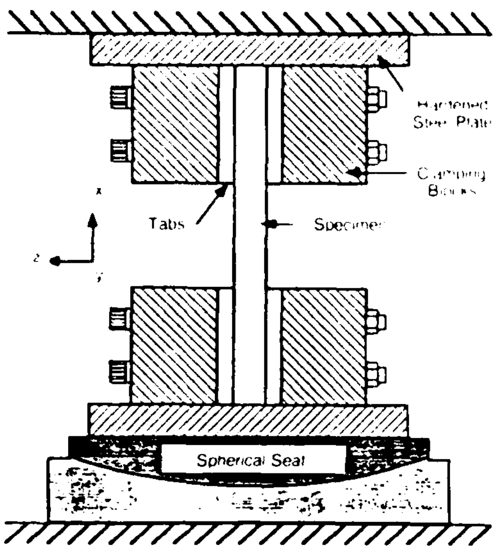

Figure 1. Cross–sectional view of the thick–section compression test fixture

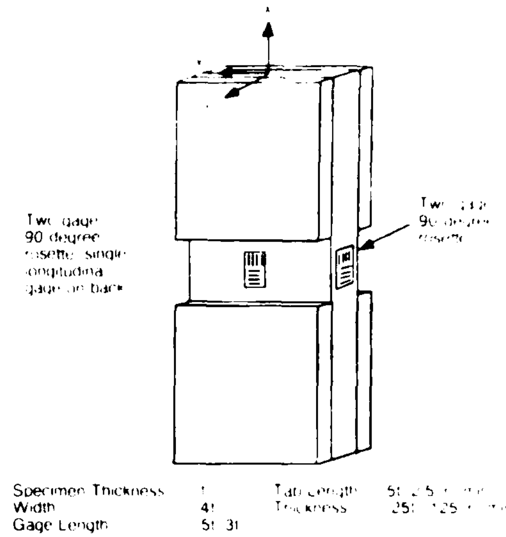

Figure 2. Specimen geometry, material directions, and strain gage locations

Dr. Eugene Camponeschi
February 1992

OHMSETT Facility Reactivated

The Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility is a unique installation constructed by the Environmental Protection Agency (EPA) to test offshore oil spill response equipment and procedures. The Naval Surface Warfare Center, Carderock Division, Carderock, Maryland, is a significant participant in the renovation, reactivation, and initial checkout of the facility. OHMSETT, when in operation, will be an environmentally safe facility to conduct testing and development of devices and techniques to control oil spills.

The Carderock Division is providing technical and administrative guidance for design, purchase, installation, and check-out of equipment required for the reactivation of the OHMSETT facility and subsequent tests.

The facility will be used to evaluate innovative detection strategies, including the use of remote sensing devices such as laser thickness sensors and laser fluorosensors for detecting oil concentration that have submerged.

Jon Etxegolen
March 1992

Non-Specular Scattering Theory Improves RCS Prediction

The Naval Surface Warfare Center, Carderock Division, Carderock, Maryland, uses prediction algorithms to estimate the radar cross section (RCS) of new designs for ships and other naval vehicles. Although these tools accurately predict specular (mirror-like) reflection, they do not accurately consider non-specular effects—traveling surface waves, creeping waves, edge effects, and whole-body mutual interaction. Research to date has demonstrated that these non-specular phenomena can have a great influence on a target's RCS, particularly for certain aspect angles or when specular returns have been reduced by application of radar absorbing materials or shape modifications.

To enhance our ability to predict and assess RCS, the Carderock Division has conducted an independent research program to improve the theories that address electromagnetic-wave scattering. Mathematical expressions have been developed to calculate the non-specular components of radar return. The approach is a hybrid solution based on the geometrical theory of diffraction and traveling surface wave theory. The integrated solution overcomes the limitations suffered by these theories when used individually.

The new theory improves scattering predictions in both the resonance and optical regions for simple targets of arbitrary length, including rods, rectangular flat plates, three-dimensional disks, wedges, and prisms. Figure 1 (a and b) illustrate the accuracy improvement for a rectangular flat plate.

The new mathematical expressions will be incorporated into existing predictive tools and will enhance Navy efforts to develop signature reduction techniques and predict the RCS vulnerability of future Navy vehicles.

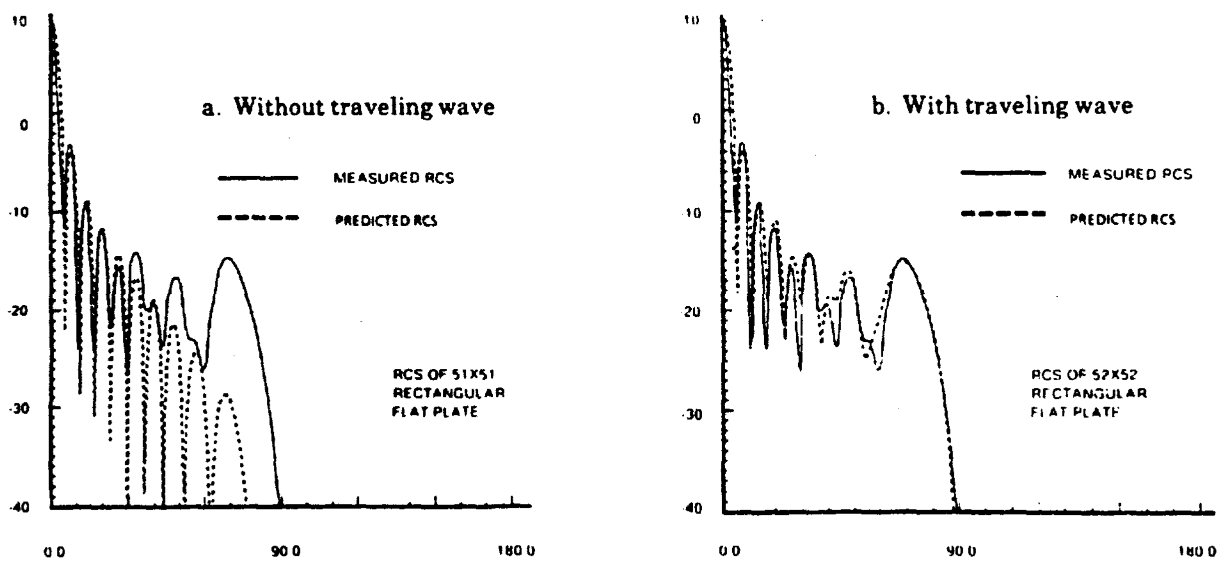

Figure 1. Flat plate back–scattering pattern

Mark Jeantheau
April 1992

CARDEROCKDIV Articles Published in *Navy Domestic Technology Transfer Fact Sheet*

Cooperative Advanced Ship Development Program Sponsored by MARAD

One positive outcome of the Ship of the Future — 2000 Conference and Workshop in May 1990 was the recent signing of an Interagency Agreement between the Naval Surface Warfare Center Carderock Division, Carderock Maryland, and the Maritime Administration (MARAD). The objectives of this agreement include establishment of the operational relationship under which MARAD and the Carderock Division will "cooperate in performing technical efforts supporting the advanced research and development of commercial and passenger vessels." The Carderock Division recently completed the first task sponsored under this agreement identified as Task 001, Ship Conceptual Design Studies under the Cooperative Advanced Ship Development Program. The Carderock Division task included background market studies and the development of conceptual ship designs for the following market opportunities: a shuttle tanker for the transfer of crude oil from offshore lightering anchorages to U.S. coastal receiving facilities, a products tanker for the transport of refined products from Caribbean refineries to U.S. coastal ports, a dry bulk carrier for the transport of U.S. preference cargoes to foreign destinations, a coastwise intercoastal roll-on roll-off vessel capable of providing military sealift in time of emergency, and an advanced technology passenger vehicle ferry for operation in U.S. coastal waters.

Donald Roseman
May 1992

High-Strength Steel Investigated

An investigation of the transition behavior of high-strength steel, martensitic weld metals was conducted at the Carderock Division of the Naval Surface Warfare Center, Carderock, Maryland, to identify the specific microstructural features that control ductile-brittle transition in these weld metals. The investigation employed a systematic approach that combined experimental measurements and observations with analytical expressions. Charpy V-notch (CVN) properties, tensile properties, and cleavage fracture stress (σ_c) were generated over a range of temperatures. The critical tensile stress criterion (CTSC) was applied in the form of a modified Griffith-Orowan expression. Transition temperatures were predicted from measurements to establish the applicability of the CTSC to the transition regime and were compared to measured CVN transition temperatures.

Predicted transition temperatures showed good agreement with measured CVN transition temperatures. This agreement quantitatively demonstrated the dependence of transition temperature on σ_c and verified the applicability of the CTSC in analyzing ductile-brittle transition behavior. CVN transition temperature and σ_c were relatively insensitive to cooling rate, suggesting that the size of the controlling microstructural feature was also insensitive to cooling rate variation. Critical microcrack sizes, calculated from σ_c measurements, ranged from 0.5 and 1.5 μm, typical of weld metal inclusion diameters.

Johnnie DeLoach
June 1992

Intelligent Control Strategy for Spray-Forming Process Developed

A control system incorporating a fuzzy logic controller and optical sensors has been developed for the spray-forming facility at the Carderock Division of the Naval Surface Warfare Center in Bethesda, Maryland. An imaging system employing laser illumination and a high-speed CCD camera provides cricital on-line preform surface roughness and rate of growth information. A fuzzy logic controller uses a ruleset to translate visual information into a form that can be reviewed by the conditional statements of the rule base. A high-performance manipulator and motion controller have also been incorporated into the spray-forming system. This project included development of optical sensors and integration of advanced control systems to determine and activate required corrective actions to the spray forming process parameters. Figure 1 shows a schematic diagram of the integrated sensing and control system.

Dr. Angela Moran
July 1992

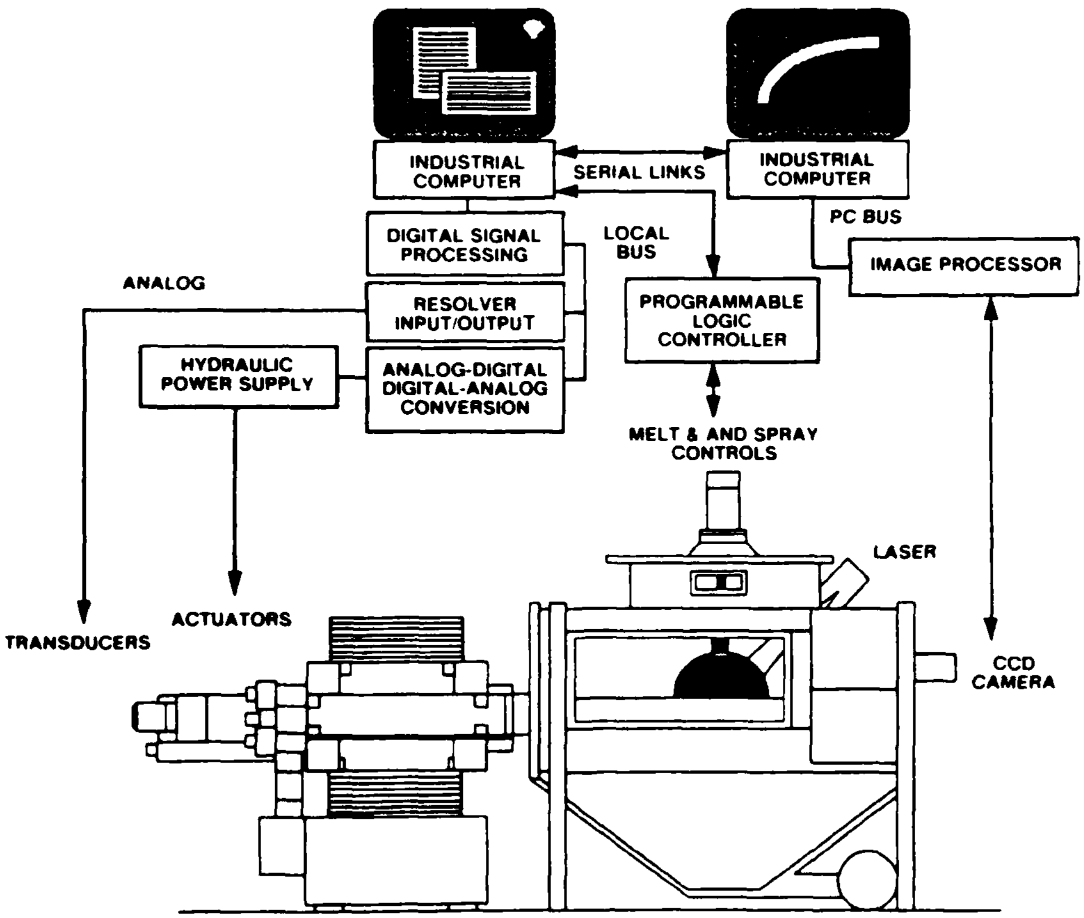

Figure 1. Integrated sensing and control system

Porosity in Composite Panels

Composite panels containing porosity were fabricated in support of a program at the Carderock Division of the Naval Surface Warfare Center, Bethesda, Maryland, investigating the moisture absorption rate and mechanical property changes of void containing composites exposed to hydrostatic pressure.

Several methods of inducing porosity into the panels during cure were investigated. The reduction in pressure during the cure cycle provided the best results. Eight panels 0.125 of an inch and four panels 0.250 of an inch in thickness were fabricated from prepreg tape containing S2 fiberglass and AS4 with a 3501-6 resin, both manufactured by Hercules Incorporated. Micrographs of uncured prepreg tapes are shown in Figures 1a and b. The panels were cured using the manufacturer's recommended cure cycle, while varying the cure pressure in 20 psi increments (90, 70, 50, 30 psi). Two 0.125-inch and one 0.250-inch panels were cured using the above mentioned pressures. On an average, the void content of S2/3501-6 panels increased by 1% for each 20 psi drop in cure pressure regardless of the thickness of the panel. The void content in the AS4/3501-6 panels was virtually nonexistent until the cure pressure was decreased to 30 psi. These results were validated through three methods: (1) ultrasonic immersion inspection, (2) microscopy, and (3) destructive evaluation.

Thomas Mixon
August 1992

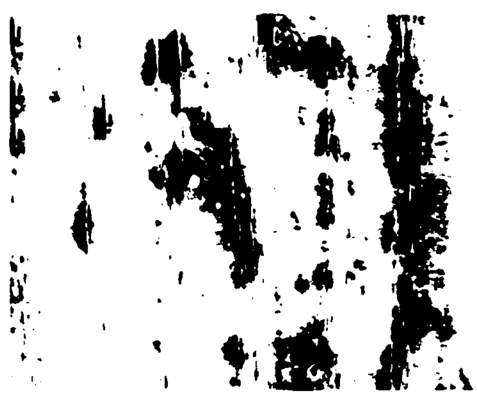

Figure 1a. Micrograph of graphite panel containing porosity

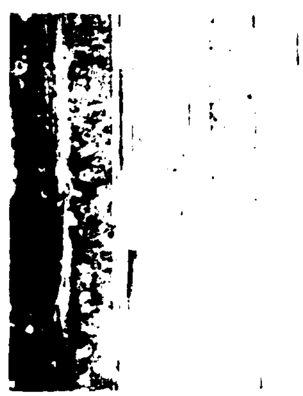

Figure 1b. Micrograph of S2/glass panel containing porosity

Waterjet Propulsion System Demonstrated

The Carderock Division of the Naval Surface Warfare Center in Bethesda, Maryland recently completed the first in a series of sea trials on the U. S. Navy's only operational Surface Effect Ship, the SES 200 (see Figure 1). Following the installation of a new and more powerful waterjet propulsion system, the trials were conducted to evaluate the ship's performance and handling under various environmental and operational conditions.

According to the officer in charge of the SES 200, the speed versus thrust data are being collected to compare the new system with the previous lower powered fixed pitch propeller system. In addition, the trials provide the crew with an opportunity to evaluate the seakeeping and ship handling characteristics.

The SES 200 was originally a 110-ft long SES that was modified structurally by the insertion of a 50 ft section amidship, to evaluate the effects of increasing length to beam ratio. The upgraded SES 200, with an improved propulsion system, is now capable of speeds in excess of 40 knots and can routinely make extended at sea deployments with only minimal shore support. This waterjet propelled SES is manned by a crew of two officers and 20 enlisted personnel from the Carderock Division's Special Trials Unit which also has a shore component. Modifications, maintenance, and supply support are provided by one officer and 15 enlisted personnel.

John Offutt
September 1992

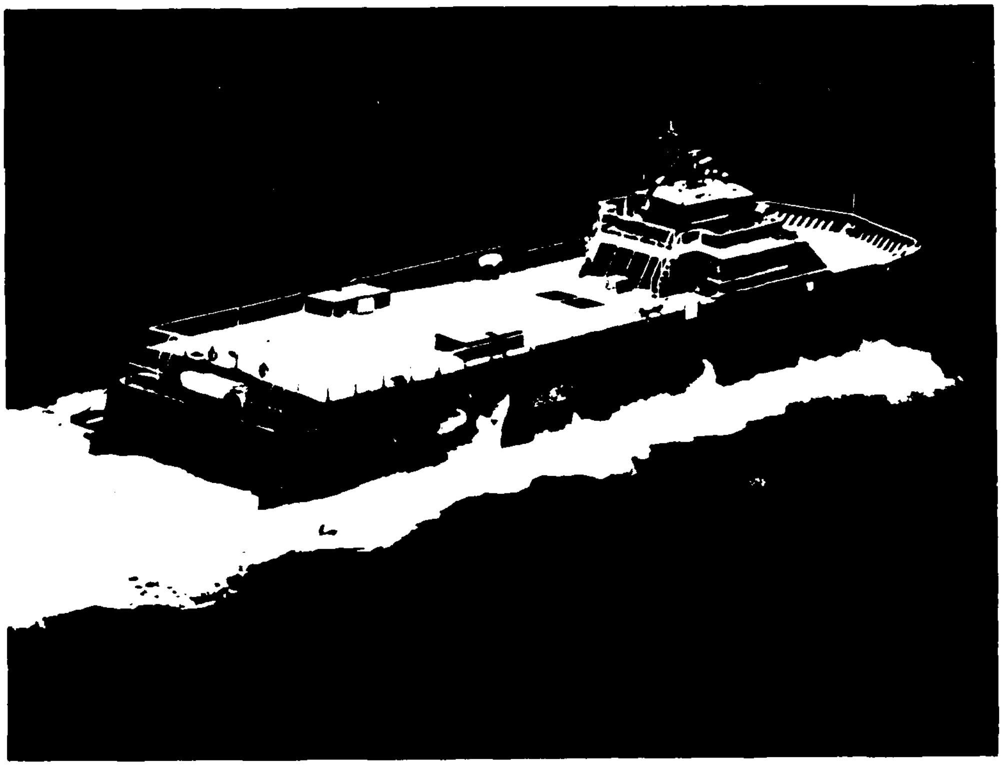

Figure 1. SES–200 with waterjet propulsion system

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Ultrasonics Identifies Planar and Volumetric Defects

Application of an artificial neural network based on a back-propagation paradigm was used by the Carderock Division of the Naval Surface Warfare Center in Annapolis, Maryland, to classify and differentiate planar and volumetric defects. A two-inch thick steel weld containing a lack of fusion defects (planar) and a block with side-drilled holes (volumetric) were inspected using time-of-flight diffraction ultrasonics.

Ultrasonic inspection, in accordance with NAVSEA 0900-LP-006-3010, *Ultrasonic Inspection Procedure and Acceptance Standards for Hull Structure Production and Repair Welds*, accepts or rejects weld defects based on combinations of amplitude, length, and proximity to other defects. The required ultrasonic procedure does not attempt to classify defects and, therefore, can inadvertently increase the rejection rates associated with weld inspection by rejecting defects that are considered to be benign to the overall structure, such as slag or porosity.

Diffracted signals were obtained from 17 unique locations and two different look angles for both the planar and volumetric defects. For each defect, 512 data points were collected from the diffracted signal at a sampling rate of 50 MHz and stored for frequency analysis. A pattern vector containing the mean, variance, coefficient of variance, coefficient of skewness, and coefficient of kurtosis was generated for each defect based on a normalized 1024-point Fourier transform of the signal. The training set for the artificial neural network constituted pattern vectors generated from 44 randomly selected signatures, half of which represented volumetric defects (see Figure 1). A test set consisting of pattern vectors from 24 signals, unique from the training set, was used to evaluate the paradigm. A classification accuracy of 95 percent was achieved for the verification test set, illustrating the potential ability to classify defects using ultrasonics in hull welds.

Lawrence Brown
October 1992

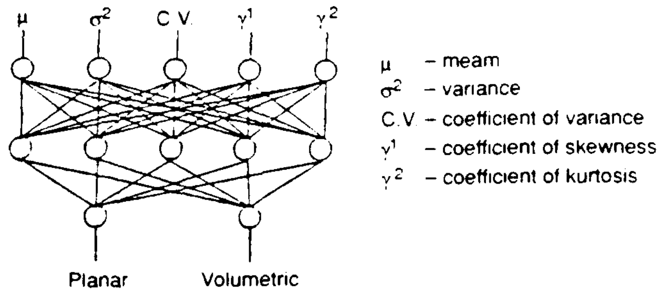

Figure 1. Three-layer artificial neural network with five input parameters, five hidden nodes, and two output variables

Environmentally Acceptable Refrigerant Developed

Over the past three years, the Carderock Division of the Naval Surface Warfare Center in Annapolis, Maryland, has been developing an environmentally acceptable refrigerant alternative to Chlorofluorocarbon-12 (CFC-12) for U.S. Navy shipboard air-conditioning plants. CFC-12 is a refrigerant that depletes the earth's protective stratospheric ozone layer and, accordingly, is being phased out of production. President Bush announced in February 1992 that the United States will discontinue CFC production after 31 December 1995.

Laboratory investigations with U.S. Navy shipboard-type 80- and 25-ton (Figures 1 and 2, respectively) air-conditioning plants have shown that HFC-134a is a suitable backfit alternative to CFC-12. A new polyol ester (POE) compressor lubricant was used, because the mineral oil previously used with CFC-12 is insoluble with HFC-134a. The full-load cooling capacity of the 80- and 25-ton air-conditioning plants increased by approximately one and five percent, respectively, when converted to use HFC-134a. Long-term extended operation investigations have demonstrated that POE provides adequate lubrication. In addition, compressor inspections have revealed all internal surfaces to be in good condition with no measurable wear.

The first conversions of fleet shipboard CFC-12 air-conditioning plants to use the environmentally acceptable refrigerant Hydrofluorocarbon 134a (HFC-134a) are underway. The air-conditioning plants onboard two U.S. Navy ships have been converted to use HFC-134a for a one-year fleet test demonstration. Three 80-ton CFC-12 plants onboard U.S.S. *DeWert* (FFG 45) were converted in April 1992, while four 50-ton CFC-12 plants onboard U.S.S. *Mount Hood* (AE 29) were converted in August 1992. Fleet-wide conversion of shipboard CFC-12 air-conditioning plants to HFC-134a will begin following the successful completion of these fleet test demonstrations.

Gregory P. Brunner
November 1992

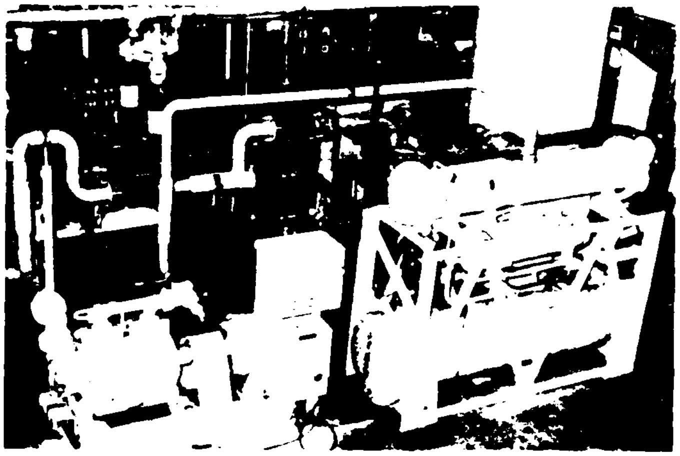

Figure 1. Shipboard-type 80-ton air-conditioning plant

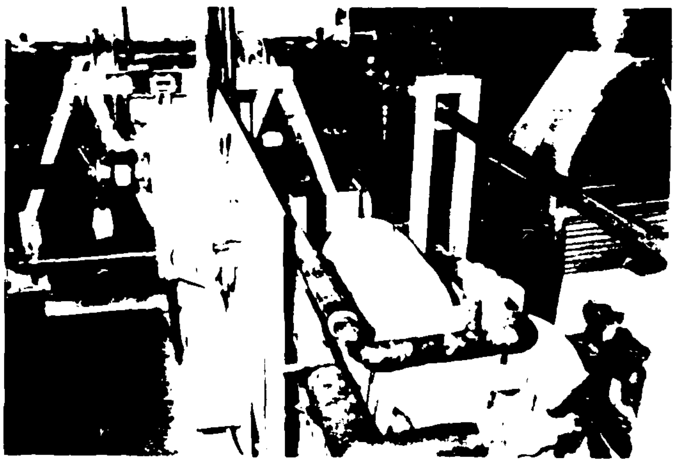

Figure 2. Shipboard-type 25-ton air-conditioning plant

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Navy Domestic Technology Transfer Fact Sheet

High-Capacity Oil/Water Separator Designed to Treat Waste

The Naval Surface Warfare Center Carderock Division, Bethesda, Maryland, has designed a High-Capacity Oil/Water Separator (HCOWS) for the treatment of bilge waste onboard CVN 68 class aircraft carriers.

The HCOWS design is based on the In-Tank Oil/Water Separator (ITOWS), which the Carderock Division developed and evaluated onboard U.S.S. *Sellers* (DDG 11). There, a contaminated oil settling tank was modified to accept closely spaced corrugated polypropylene parallel plates, which facilitate the removal of oil from water. In effect, the tank became a large oil/water separator similar to the Navy-approved Models OPB-10N and OPB-10NP, with the processing flow rate expanded from 10 gallons per minute to 15-60 gallons per minute.

Based on the successful system evaluation on DDG 11, an ITOWS was designed, built, and evaluated in the laboratory at flow rates of 50 to 200 gallons per minute to satisfy the processing requirements of aircraft carriers and other Navy vessels. At the same time, Carderock Division and the Johns Hopkins University developed a computer model to improve in-tank designs and extend parallel-plate oil-water separator technology to bilge processing applications fleetwide. The ITOWS laboratory studies and the computer model were used together to design the HCOWS for CVN 68 class ships.

Ray F. Schmitt
December 1992

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